Photoemission spectromicroscopy studies on inhomogeneities on epitaxial lateral overgrowth GaN surfaces

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INTRODUCTION

Gallium nitride (GaN) materials are very useful for fabricating electronic and electro-optic devices, such as high power electronics, blue and ultraviolet light emitting diodes (LED), detectors, and laser devices.[1,2,3] However, the development of III-V nitride materials and devices has suffered from the lack of the availability of low-dislocation-density, lattice-matched substrates for device synthesis. Recently, epitaxial lateral overgrowth (ELO) technique[4] produces GaN with a remarkable reduction of the dislocation density to about 10^4 per cm^2 or less. This method starts with a layer of GaN on sapphire (or SiC) which is then patterned with SiO_2 stripes separated by windows. The final MOVPE growth starts in the windows growing up and over the SiO_2 stripes because the film will not “seed” on it. Between two adjacent final stripes is where the growth fronts meet and coalesce. It is above the middle of the SiO_2 stripes. Properties of the Ga3d photoemission line are found to be dependent on the various regions in the structure.

EXPERIMENTS

In this work, synchrotron-radiation-based photoemission spectromicroscopy was performed to investigate the inhomogeneities in the electronic structures of the ELO GaN surfaces. The MAXIMUM microscope[5] on beamline 12 at ALS is used for the studies, which operates at photon energy of 130 eV. The photon energy is quite appropriate for semiconductor investigations. Data are collected in two modes: (a) the scanning mode where a 2-D image is acquired by measuring the photoelectrons in a given kinetic energy window, and (b) the microprobe mode where an energy distribution curve (EDC) is acquired at the position of interest. The spatial resolution in this experiment is 0.5 μm. A cylindrical mirror analyzer (CMA) is used to detect the energy-resolved emission. The overall energy resolution is about 0.4 eV.

RESULTS

The scanning-mode measurement of the photoemission signal with the spectromicroscope is used to obtain an overview. Figure 1(a) is the image and (b) is the line profile. The 100X100 μm^2 image is acquired with a step size of 1 μm by recording the signal from Ga 3d core-level emission peak at a kinetic energy of 104.0 eV. In the image, bright areas correspond to stripes of GaN and dark areas are the meeting-front grooves. The contrast mechanism producing the spectromicroscopy image is largely due to the angular dependence of the photoemission yield combined with different orientations of plateau areas and the valley areas.

For better understanding of inhomogeneities of the sample's surface electronic structure, high-energy-resolution local EDC's for the Ga 3d core level are obtained from the sample at positions labeled a, b, c, d and e on the image. "a" and "e" sit on meeting-front areas, "b" and "d" are on the lateral overgrow area and "c" on the vertical-growth window area, respectively. The spectra are shown in Fig. 2(a) where the five EDC's are normalized to the same peak intensity. The EDC's labeled "a" and "e", from the meeting-front areas show an energy shift of 0.15 eV compared with the EDC's from the flat area. The observed peak shift is attributed to a change in the surface-Fermi-level position for the crystal orientation of the growth fronts ($(1\bar{1}01)$ in this case[6]) compared to (0001) orientation of the flat areas.

While the EDC's from the flat area all have the same binding energies, a change is found in their line shape. At point "c" which is in the window area the line is slightly narrower than those from point "b" and "d". The difference curve "d-c" is shown in Fig. 2(a). Figure 2(b) is the difference for "b-d" which shows no feature. The EDC for point "d" has increased emission at 105.5 eV and 104.7 eV. From previous studies, a surface shifted component exists on the lower kinetic energy side[7]. So far no clean surface peak have been found on the high kinetic energy side. We suggest that better surface structure quality indicate better crystal quality for the ELO region. Another possible interpretation is some kind of inhomogeneities broadening which is not considered in this case because the effect should be larger for the defect heavy window region.

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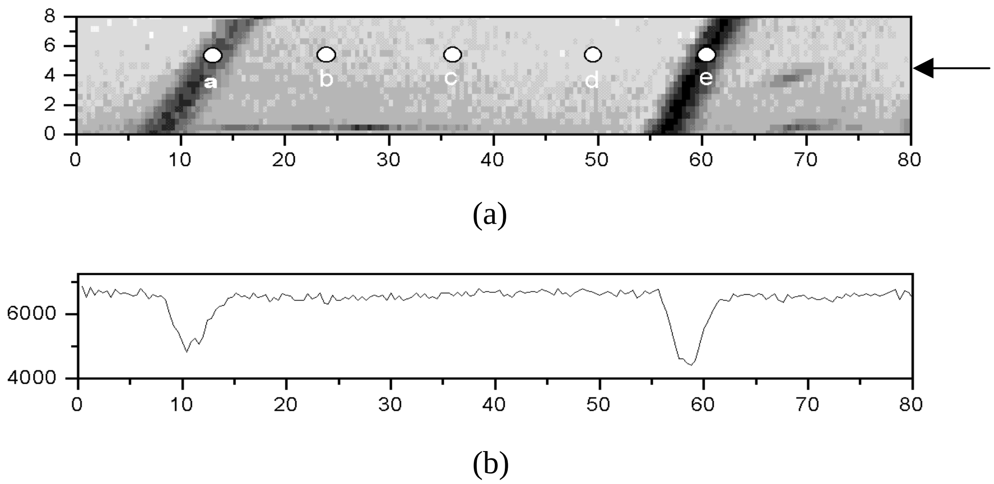

Figure 1 (a) A photoemission spectromicroscopy image for a 80X8 μm^2 area of the ELO GaN surface (sample M287) formed by the signal at the peak position of the Ga 3d core level emission at a kinetic energy of 104.0 eV. (b) A line profile obtained at the position marked by the arrow.

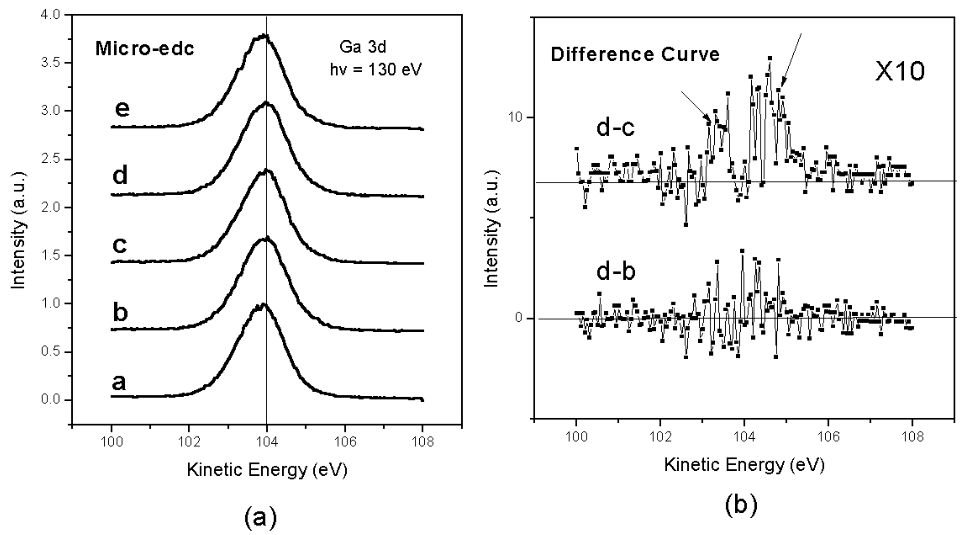

Figure 2 (a) Micro-EDC’s of Ga 3d core level emission from different areas on the sample surface, curve “a” and “e” are taken at the meeting front areas, “b” and “e” from the overgrowth area, “c” from the window area. (b)Difference curve “d-b” shows no feature, demonstrating the uniformity on the lateral overgrowth area. Curve “d-c” reveals the inhomogeneities between the overgrowth area and the window area, two features indicated by arrows are observed.